of significant importance in view of the high cost and lack of understanding of the environmental consequences associated with alternatives to open water disposal. However, as in the discussion of sampling techniques, it appears that these two views may persist for some time. It is possible, with adequate quality control, that the results obtained solely for the purposes of determining pollution status will become more meaningful with additional research.

Recommendations. The following are recommended:

a. Expansion and standardization of the techniques for preliminary sample preparation as set forth in reference 10.

b. Incorporation of physical parameters such as particle size distribution.

c. Utilization and standardization of current chemical techniques that permit fractionalization of the results.

(1) Quantify constituents sorbed on the solid phase.

(2) Quantify constituents in the interstitial water phase.

(3) Quantify constituents in the bulk of free water stage.

d. Utilization and standardization of chemical techniques for determining sorption capacities of various sediments.

e. Utilization and standardization of chemical techniques for determining sediment sorption preferences: anionic and cationic exchange capacities.

f. Development of constituent leaching rates as a function of:

(1) Bottom sediment or spoil characteristics.

(2) Constituent phase and incorporation in the sample.

(3) Varying environmental (water quality) conditions, e.g., Eh and pH.

(4) Varying environmental physical conditions, e.g., natural sediment/water mixing.

(5) Mechanical sediment/water mixing due to dredging and disposing.

g. Utilization and standardization of analytical biological procedures

(1) Photosynthesis/Respiration (P/R) techniques.

(2) Trophic level bioassays.

(3) Biotic indices.

(4) Primary productivity.

(5) Diversity indices.

Pollution Determination

That there will be rules and regulations, criteria, standards, recommendations, and additional legislation pertaining to the Corps dredging operations is obvious. The Water Quality Improvement Act of 1970 which requires permits for discharges into navigable waters and the Environmental Policy Act of 1969 requiring the preparation of "Environmental Impact Statements" on certain Federal activities (including dredging) are two examples. The EPA criteria[9] have been mentioned earlier and are discussed in more detail below. While it is acknowledged in this study that some form of control over open water dredging operations is desirable and necessary, it is strongly stressed that such controls (i.e., rules, criteria, standards) should be based on solid technical information with provisions for (a) periodic review and update, and (b) the regional variability found throughout the nation's marine and fresh waters.

Although excerpts have been presented earlier, the entire text of the EPA criteria is presented below for purposes of discussion and clarification.

CRITERIA FOR DETERMINING ACCEPTABILITY OF DREDGED SPOIL DISPOSAL TO THE NATION'S WATERS

Use of Criteria

These criteria were developed as guidelines for FWQA evaluation of proposals and applications to dredge sediments from fresh and saline waters.

Criteria

The decision whether to oppose plans for disposal of dredged spoil in United States waters must be made on a case-by-case basis after considering all appropriate factors; including the following:

(a) Volume of dredged material.

(b) Existing and potential quality and use of the water in the disposal area.

(c) Other conditions at the disposal site such as depth and currents.

(d) Time of year of disposal (in relation to fish migration and spawning, etc.).

(e) Method of disposal and alternatives.

(f) Physical, chemical, and biological characteristics of the dredged material.

(g) Likely recurrence and total number of disposal requests in a receiving water area.

(h) Predicted long and short term effects on receiving water quality. When concentrations, in sediments, of one or more of the following pollution parameters exceed the limits expressed below, the sediment will be considered polluted in all cases and, therefore, unacceptable for open water disposal.

Sediments in Fresh and Marine Waters	Conc. % (dry wt. basis)
*Volatile Solids	6.0
Chemical Oxygen Demand (C.O.D.)	5.0
Total Kjeldahl Nitrogen	0.10
Oil-Grease	0.15
Mercury	0.001
Lead	0.005
Zinc	0.005

*When analyzing sediments dredged from marine waters, the following correlation between volatile solids and C.O.D. should be made:

$$T.V.S.\%\ (dry) = 1.32 + 0.98(C.O.D.\%)$$

If the results show a significant deviation from this equation, additional samples should be analyzed to insure reliable measurements.

The volatile solids and C.O.D. analyses should be made first. If the maximum limits are exceeded the sample can be characterized as polluted and the additional parameters would not have to be investigated.

Dredged sediment having concentrations of constituents less than the limits stated above will not be automatically considered acceptable for disposal. A judgement must be made on a case-by-case basis after considering the factors listed in (a) through (h) above.

In addition to the analyses required to determine compliance with the stated numerical criteria, the following additional tests are recommended where appropriate and pertinent:

Total Phosphorus
Total Organic Carbon (T.O.C.)
Immediate Oxygen Demand (I.O.D.)
Settleability
Sulfides
Trace Metals (iron, cadmium, copper, chromium, arsenic, and nickel)
Pesticides
Bioassay

> The first four analyses would be considered desirable in almost all instances. They may be added to the mandatory list when sufficient experience with their interpretation is gained. For example, as experience is gained, the T.O.C. test may prove to be a valid substitute for the volatile solids and C.O.D. analyses. Tests for trace metals and pesticides should be made where significant concentrations of these materials are expected from known waste discharges.
>
> All analyses and techniques for sample collection, preservation, and preparation shall be in accord with a current FWQA analytical manual on sediments.

Discussion of the required techniques for sampling and analysis, as set forth in the referenced FWQA analytical manual on sediments, was presented in an earlier portion of this report.

The cited factors (a-h) to be used in determining whether to oppose plans for open water disposal appear from a technical standpoint to be quite valid. It is difficult to understand, however, how a decision of such significance can be made when, except in rare circumstances, there is little if any data available on points (b), (c), (f), and especially (h). The situation becomes even more frustrating when, as can be seen, there are no instructions, guidelines, or standards pertaining to the collection, analysis, interpretation, or dissemination of such information.

As can be seen, the actual criteria consist of only seven parameters applicable to all fresh and marine waters of the United States. As stated, if the concentration of any one of these parameters is exceeded, the bottom materials are unacceptable for open water disposal. A disturbing aspect of this statement is that, as far as can be determined, there is no provision in these criteria for total sample number, frequency, or distribution. In other words, although only one parameter has to be exceeded before the material is classified as polluted, is this decision based on 1 percent, 5 percent, 25 percent, etc., of all samples? Carried to the extreme, would analysis of one sample (1/2 cu ft) be sufficient to represent the pollution status of a 100,000-cu-yd project? It seems possible that with knowledge of the anticipated total area and volume of materials to be dredged, estimates of the total number of samples needed for a representative description of the project could be derived.

From the assessment portion of this study, it appears that the seven parameters can, in a generalized manner, be divided into two categories based on their effects and manner of association with the bottom sediments. The first category would include materials such as natural organic and sewage sludges that are mixed in with other sediments and that, when dredged and spoiled in open waters, can exert a short-term oxygen demand. Parameters indicative of this category include volatile solids, chemical oxygen demand, and to some extent, total Kjeldahl nitrogen. The second category is comprised of heavy metals that are either physically or chemically sorbed or bound within the sediment matrix and for which the short- or long-term effects due to dredging are difficult to predict with any degree of certainty. Parameters indicative of this category include mercury, lead, and zinc.

Because of the qualitative nature of the oil and grease analytical procedure, various compounds can be classified as oil-grease. These compounds vary in their effects and their manner of association with bottom sediments. These compounds can therefore be classified under either of the above categories.

A review of the literature failed to indicate on what basis the concentrations associated with the seven pollution parameters were derived. There appear to be strong reservations within the scientific community over the current tendency to use the chemical composition of spoil material as the sole indicator of pollution status. Bioassays performed by the University of Wisconsin in connection with the Great Lakes studies[5] did suggest a relationship between the chemical nature of sediments and their toxic and algal-growth-promoting potentials. These studies were requested by the Board of Consultants*

* Charged to serve in an advisory capacity to the Corps in relation to the Great Lakes dredging and water quality studies.[5]

to shed more light on the effects of disposing polluted dredged materials in the open lakes (monitoring studies along these lines were inconclusive). Presumably, results from these bioassays were part of the evidence leading to the following conclusion by the Board of Consultants:

> Just what the long-term impact of this practice (open-water disposal) will be on lake eutrophication and useful water quality cannot yet be stated unequivocally, in the opinion of the Board, even though it must be acknowledged that in-lake disposal of heavily polluted dredgings must be considered presumptively undesirable because of its long term adverse effects on the ecology of the Great Lakes.

It should be pointed out that the investigators involved with the mentioned bioassay studies warned about the direct applicability of the findings to nature. Also, the Board of Consultants recommended that further research be conducted and that "A correctional campaign based on inadequate evidence may be self-defeating." Such a statement attains even greater significance when viewed from a national context.

It has not been possible to determine what evidence supports the given correlation equation between volatile solids and C.O.D. Statements accompanying the equation imply that data failing to fit this equation are not reliable and that additional tests (and expenditures) are necessary to ensure reliability. Both of these parameters are a function not only of how they are determined, but of the types of materials present in each sample.[11] There appears little reason to believe that this equation is reliable—especially to the given three significant figures—in all sediments in all marine waters in the United States.

The criteria mention additional parameters that should be determined "where appropriate and pertinent" and that total phosphorus, total organic carbon, immediate oxygen demand, and settleability are "considered desirable in almost all instances." Yet no numerical criteria are given for these parameters and the referenced analytical manual for sediments includes no instructions for total organic carbon or settleability. It is assumed that these additional parameters should be determined according to the procedures in "Methods for Chemical Analyses of Water and Wastes,"[12] or "Standard Methods for the Examination of Water and Wastewater."[11]

According to Ciaccio,[13] the following critical differences exist in the meaning of the words "criterion" and "standard."

> A "standard" is a definite rule, principle, or measure established by authority. Since it is established by authority, it is official or quasi-legal. However, because something is termed a standard does not mean that it is rationally based on the best scientific knowledge and engineering practice. Use of a standard tends to eliminate improvement and sustain inflexibility.
>
> The term "criterion" designates a scientific requirement on which a judgement or decision to support a particular use may be based. A criterion should be capable of quantitative evaluation by existing analytical tests and also be capable of definite resolution. In contrast to standards, criteria have no connotation of authority. When data are gathered to be used as a yardstick of water quality, "criterion" is the proper term.

Because the current EPA requirements concerning the Corps' dredging operations are in the form of criteria, it is strongly urged that every effort be made to review, update, and expand these current criteria. It is further recommended that:

a. The updated criteria be based on the best possible technological basis.

b. The criteria be in a flexible format that would provide necessary, regionalized control and simultaneously provide a continuous source of useful information on a national basis to aid in assessment of dredging operations and in the periodic update of criteria.

c. That many of the research efforts in Phase III of this study be designed to provide the technological basis for continually improving the criteria.